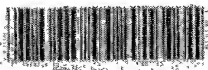
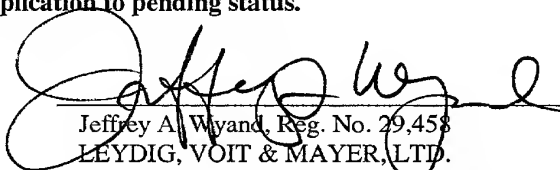


U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE  <b>TRANSMITTAL LETTER TO THE UNITED STATES</b> <b>DESIGNATED/ELECTED OFFICE (DO/EO/US)</b> <b>CONCERNING A FILING UNDER 35 USC 371 AND 37 CFR 1.491</b>		ATTORNEY DOCKET NO.  401530 U.S. APPLICATION NO. <b>10/030986</b> PRIORITY DATE CLAIMED
INTERNATIONAL APPLICATION NO. PCT/JP00/03994	INTERNATIONAL FILING DATE June 19, 2000	
TITLE OF INVENTION <b>EXCITATION CONTROL DEVICE AND EXCITATION CONTROL METHOD</b>		
APPLICANT(S) FOR DO/EO/US <b>KITAMURA ET AL.</b>		
Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:		
1. <input checked="" type="checkbox"/> This is a <b>FIRST</b> submission of items concerning a filing under 35 USC 371 and 37 CFR 1.491.		
2. <input type="checkbox"/> This is a <b>SECOND</b> or <b>SUBSEQUENT</b> submission of items concerning a filing under 35 USC 371 and 37 CFR 1.491.		
3. <input checked="" type="checkbox"/> This is an express request to begin national examination procedures (35 USC 371(f)).		
4. <input checked="" type="checkbox"/> The US has been elected by the expiration of 19 months from the priority date (PCT Article 31).		
5. <input checked="" type="checkbox"/> A copy of the International Application as filed (35 USC 371(c)(2)) <ul style="list-style-type: none"> <li>a. <input type="checkbox"/> is attached hereto (required only if not communicated by the International Bureau).</li> <li>b. <input checked="" type="checkbox"/> has been communicated by the International Bureau.</li> <li>c. <input type="checkbox"/> is not required, as the application was filed in the United States Receiving Office (RO/US).</li> </ul>		
6. <input type="checkbox"/> An English language translation of the International Application as filed (35 USC 371(c)(2)).		
7. <input checked="" type="checkbox"/> Amendments to the claims of the International Application under PCT Article 19 (35 USC 371(c)(3)) <ul style="list-style-type: none"> <li>a. <input type="checkbox"/> are attached hereto (required only if not communicated by the International Bureau).</li> <li>b. <input type="checkbox"/> have been communicated by the International Bureau.</li> <li>c. <input type="checkbox"/> have not been made; however, the time limit for making such amendments has NOT expired.</li> <li>d. <input checked="" type="checkbox"/> have not been made and will not be made.</li> </ul>		
8. <input type="checkbox"/> An English language translation of the amendments to the claims under PCT Article 19 (35 USC 371(c)(3)).		
9. <input checked="" type="checkbox"/> An oath or declaration of the inventor(s) (35 USC 371(c)(4)).		
10. <input type="checkbox"/> An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 USC 371(c)(5)).		
11. Nucleotide and/or Amino Acid Sequence Submission <ul style="list-style-type: none"> <li>a. <input type="checkbox"/> Computer Readable Form (CRF)</li> <li>b. Specification Sequence Listing on:                         <ul style="list-style-type: none"> <li>i. <input type="checkbox"/> CD-ROM or CD-R (2 copies); or</li> <li>ii. <input type="checkbox"/> Paper Copy</li> </ul> </li> <li>c. <input type="checkbox"/> Statement verifying identity of above copies</li> </ul>		
<b>Items 12 to 19 below concern other document(s) or information included:</b>		
12. <input checked="" type="checkbox"/> An Information Disclosure Statement under 37 CFR 1.97 and 1.98. <ul style="list-style-type: none"> <li><input checked="" type="checkbox"/> Form PTO-1449</li> <li><input checked="" type="checkbox"/> Copies of Listed Documents</li> </ul>		
13. <input checked="" type="checkbox"/> An assignment for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.		
14. <input checked="" type="checkbox"/> A <b>FIRST</b> preliminary amendment. <input type="checkbox"/> A <b>SECOND</b> or <b>SUBSEQUENT</b> preliminary amendment.		
15. <input type="checkbox"/> A substitute specification.		
16. <input type="checkbox"/> A change of power of attorney and/or address letter.		
17. <input checked="" type="checkbox"/> Application Data Sheet Under 37 CFR 1.76		
18. <input checked="" type="checkbox"/> Return Receipt Postcard		
19. <input checked="" type="checkbox"/> Other items or information: Drawings (7 sheets)		

U.S. APPLICATION NO. <b>10/030986</b>		INTERNATIONAL APPLICATION NO. PCT/JP00/03994		ATTORNEY DOCKET NO. 401530			
20. <input checked="" type="checkbox"/> The following fees are submitted: <b>Basic National Fee (37 CFR 1.492(a)(1)-(5)):</b> Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO..... \$1,040.00 International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO..... \$890.00 International preliminary examination fee (37 CFR 1.482) not paid to USPTO, but international search fee (37 CFR 1.445(a)(2)) paid to USPTO..... \$740.00 International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4) ..... \$710.00 International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1) to (4)..... \$100.00				CALCULATIONS		PTO USE ONLY	
ENTER APPROPRIATE BASIC FEE AMOUNT=				\$890.00			
Surcharge of \$130.00 for furnishing the National fee or oath or declaration later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date				\$			
CLAIMS		NUMBER FILED		NUMBER EXTRA		RATE	
Total Claims		4		-20=		x \$ 18.00	
Independent Claims		2		- 3 =		x \$ 84.00	
<input type="checkbox"/> Multiple Dependent Claim(s) (if applicable)				+\$280.00		\$	
TOTAL OF ABOVE CALCULATIONS=				\$890.00			
<input type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2.				\$			
SUBTOTAL=				\$890.00			
Processing fee of \$130.00 for furnishing English Translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date.				\$			
TOTAL NATIONAL FEE=				\$890.00			
Fee for recording the enclosed assignment. The assignment must be accompanied by an appropriate cover sheet. \$40.00 per property				+		\$40.00	
TOTAL FEE ENCLOSED=				\$930.00			
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a. <input checked="" type="checkbox"/> A check in the amount of \$930.00 to cover the above fee is enclosed. b. <input type="checkbox"/> Please charge Deposit Account No. 12-1216 in the amount of \$ to cover the above fees. A duplicate copy of this sheet is enclosed. c. <input checked="" type="checkbox"/> The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 12-1216. A duplicate copy of this sheet is enclosed.							
<b>NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.</b>							
SEND ALL CORRESPONDENCE TO:							
 <b>23548</b> PATENT TRADEMARK OFFICE		 Jeffrey A. Wyand, Reg. No. 29,458 LEYDIG, VOIT & MAYER, LTD. 700 Thirteenth Street, N.W., Suite 300 Washington, DC 20005-3960 (202) 737-6770 (telephone) (202) 737-6776 (facsimile)					
		Date: <u>January 16, 2002</u>					

PATENT  
Attorney Docket No. 401530/SHINSEI

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:

KITAMURA et al.

Art Unit: Unassigned

Application No. Unassigned

Examiner: Unassigned

Filed: January 16, 2002

For: EXCITATION CONTROL DEVICE AND  
EXCITATION CONTROL METHOD

PRELIMINARY AMENDMENT

Commissioner for Patents  
Washington, D.C. 20231

Dear Sir:

Prior to the examination of the above-identified patent application, please enter the following amendments and consider the following remarks.

*IN THE CLAIMS:*

Replace the indicated claims with:

1. (Amended) An excitation control device comprising:  
voltage detecting means for detecting a voltage of an output terminal of a synchronous machine which is connected to a power transmission system through a transformer;  
reactive current detecting means for detecting a reactive current output from the synchronous machine;  
voltage setting means for setting a reference voltage of the output terminal of the synchronous machine according to the reactive current detected by the reactive current detecting means, a reference voltage of an output side of the transformer, and a phase compensation transfer function to quicken attenuation of an electric power fluctuation; and  
control means for controlling an exciting system of the synchronous machine according to a difference between the reference voltage set by the voltage setting means and the voltage of the output terminal of the synchronous machine detected by the voltage detecting means.

2. (Amended) The excitation control device according to claim 1, wherein the reference voltage of the output terminal of the synchronous machine is set by the voltage setting means based on the voltage of the output terminal of the synchronous machine detected by the voltage detecting means.

3. (Amended) An excitation control method, comprising:  
detecting a voltage of an output terminal of a synchronous machine which is connected to a power transmission system through a transformer;  
detecting a reactive current output from the synchronous machine;  
setting a reference voltage of the output terminal of the synchronous machine according to the reactive current, a reference voltage of an output side of the transformer, and a phase compensation transfer function to quicken attenuation of an electric power fluctuation; and  
controlling an exciting system of the synchronous machine according to a difference between the reference voltage of the output terminal of the synchronous machine and the voltage of the output terminal of the synchronous machine.

4 (Amended) The excitation control method according to claim 3, wherein setting the reference voltage of the output terminal of the synchronous machine includes setting the reference voltage of the output terminal of the synchronous machine based on the voltage of the output terminal of the synchronous machine.

*IN THE ABSTRACT:*

Replace the Abstract with:

ABSTRACT OF THE DISCLOSURE

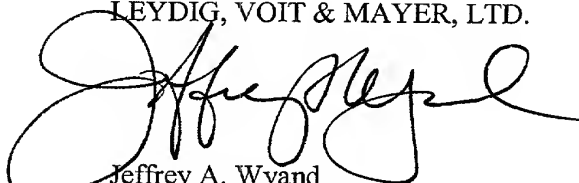
A reference voltage of an output terminal of a synchronous machine is set according to a reactive current output from the synchronous machine, a reference voltage of the high voltage side of a transformer, and a phase compensation transfer function to quicken attenuation of an electric power fluctuation.

**REMARKS**

The foregoing Amendment corrects translational errors and conforms the claims to United States practice. No new matter is added.

Respectfully submitted,

LEYDIG, VOIT & MAYER, LTD.



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Date:

*January 16, 2002*

JAW:ves

PATENT  
Attorney Docket No. 401530/SHINSEI

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

In re Application of:

KITAMURA et al.

Application No. Unassigned

Art Unit: Unassigned

Filed: January 16, 2002

Examiner: Unassigned

For: EXCITATION CONTROL DEVICE  
AND EXCITATION CONTROL  
METHOD

**AMENDMENTS TO CLAIMS AND  
ABSTRACT MADE VIA PRELIMINARY AMENDMENT**

*Amendments to existing claims:*

1. (Amended) An excitation control device, comprising:  
voltage detecting means for detecting a voltage of an output terminal of a synchronous machine which is connected to a power transmission system through a transformer;  
reactive current detecting means for detecting a reactive current output from the synchronous machine;  
voltage setting means for setting a reference voltage of the output terminal of the synchronous machine according to the reactive current detected by the reactive current detecting means, a reference voltage of an output side of the transformer, and a function of phase compensation ~~used~~ transfer function to quicken ~~the~~ attenuation of an electric power fluctuation; and  
control means for controlling an exciting system of the synchronous machine according to a difference between the reference voltage set by the voltage setting means and the voltage of the output terminal of the synchronous machine detected by the voltage detecting means.
2. (Amended) ~~An~~ The excitation control device according to claim 1, wherein the reference voltage of the output terminal of the synchronous machine is set by the voltage setting means ~~by considering~~ based on the voltage of the output terminal of the synchronous machine detected by the voltage detecting means.

3. (Amended) ~~An~~ An excitation control method, comprising ~~the steps of~~:  
detecting a voltage of an output terminal of a synchronous machine which is connected to a power transmission system through a transformer;  
detecting a reactive current output from the synchronous machine;  
setting a reference voltage of the output terminal of the synchronous machine according to the reactive current, a reference voltage of an output side of the transformer, and ~~a function of~~ phase compensation ~~used~~ transfer function to quicken ~~the~~ attenuation of an electric power fluctuation; and  
controlling an exciting system of the synchronous machine according to a difference between the reference voltage of the output terminal of the synchronous machine and the voltage of the output terminal of the synchronous machine.

4. (Amended) ~~An~~ The excitation control method according to claim 3, wherein ~~the step of~~ setting the reference voltage of the output terminal of the synchronous machine includes ~~the step of~~ setting the reference voltage of the output terminal of the synchronous machine ~~by considering~~ based on the voltage of the output terminal of the synchronous machine.

*Amendments to the abstract:*

#### ABSTRACT OF THE DISCLOSURE

A reference voltage  $V_{Gref}$  of an output terminal of a synchronous machine ~~21~~ is set according to a reactive current  $I_Q$  output from the synchronous machine ~~21~~, a reference voltage  $V_{Href}$  of the high voltage side of a transformer ~~22~~, and ~~a transfer function~~  $F_{H1}(s)$  of phase compensation ~~used~~ transfer function to quicken ~~the~~ attenuation of an electric power fluctuation.

PATENT  
Attorney Docket No. 401530/SHINSEI

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

In re Application of:

KITAMURA et al.

Application No. Unassigned

Art Unit: Unassigned

Filed: January 16, 2002

Examiner: Unassigned

For: EXCITATION CONTROL DEVICE  
AND EXCITATION CONTROL  
METHOD

**PENDING CLAIMS AFTER ENTRY OF PRELIMINARY AMENDMENT**

1. An excitation control device comprising:  
voltage detecting means for detecting a voltage of an output terminal of a synchronous machine which is connected to a power transmission system through a transformer;  
reactive current detecting means for detecting a reactive current output from the synchronous machine;  
voltage setting means for setting a reference voltage of the output terminal of the synchronous machine according to the reactive current detected by the reactive current detecting means, a reference voltage of an output side of the transformer, and a phase compensation transfer function to quicken attenuation of an electric power fluctuation; and  
control means for controlling an exciting system of the synchronous machine according to a difference between the reference voltage set by the voltage setting means and the voltage of the output terminal of the synchronous machine detected by the voltage detecting means.
2. The excitation control device according to claim 1, wherein the reference voltage of the output terminal of the synchronous machine is set by the voltage setting means based on the voltage of the output terminal of the synchronous machine detected by the voltage detecting means.
3. An excitation control method, comprising:  
detecting a voltage of an output terminal of a synchronous machine which is connected to a power transmission system through a transformer;  
detecting a reactive current output from the synchronous machine;



setting a reference voltage of the output terminal of the synchronous machine according to the reactive current, a reference voltage of an output side of the transformer, and a phase compensation transfer function to quicken attenuation of an electric power fluctuation; and

controlling an exciting system of the synchronous machine according to a difference between the reference voltage of the output terminal of the synchronous machine and the voltage of the output terminal of the synchronous machine.

4 The excitation control method according to claim 3, wherein setting the reference voltage of the output terminal of the synchronous machine includes setting the reference voltage of the output terminal of the synchronous machine based on the voltage of the output terminal of the synchronous machine.

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SPECIFICATION

## TITLE OF THE INVENTION

EXCITATION CONTROL DEVICE AND EXCITATION CONTROL METHOD

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## TECHNICAL FIELD

The present invention relates to an excitation control device and an excitation control method used for both the stabilization of voltage in an electric power system and the improvement of steady-state stability in the electric power system.

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## BACKGROUND ART

Fig. 1 is constitutional view of a conventional excitation control device. In Fig. 1, 1 indicates a synchronous machine. 2 indicates a transformer. 3 indicates a circuit breaker. 4 indicates a power transmission line. 5 indicates a power transmission bus line. 6 indicates a potential transformer (hereinafter, called PT) for detecting a voltage  $V_e$  of an output terminal of the synchronous machine 1. 7 indicates a current transformer (hereinafter, called CT) for detecting a reactive current  $I_q$  output from the synchronous machine 1. 8 indicates a voltage setting device for setting a reference voltage  $V_{Gref}$  of the output terminal of the synchronous machine 1 according to both the reactive current  $I_q$  detected in the CT 7 and a reference voltage  $V_{Href}$  of the high voltage side of the transformer 2.

9 indicates a subtracting unit for subtracting the output terminal voltage  $V_e$  detected in the PT 6 from the reference voltage  $V_{Gref}$  set in the voltage setting device 8 to obtain a subtraction value and outputting a difference signal indicating the subtraction value. 10 indicates an automatic voltage regulating device (hereinafter, called AVR) for controlling a commutation timing of an exciter 11 by using

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the difference signal output from the subtracting unit 9 as an input condition for a transfer function. 11 indicates the exciter for supplying a field current to a field winding 12 of the synchronous machine 1 according to an instruction of the AVR 10. 12 indicates the field winding of the synchronous machine 1.

Fig. 2 is a flow chart showing a conventional excitation control method.

Next, an operation will be described.

A voltage  $V_g$  of the output terminal of the synchronous machine 1 is detected in the PT 6 (step ST1), and a reactive current  $I_q$  output from the synchronous machine 1 is detected in the CT 7 and the PT 6 (step ST2).

When the reactive current  $I_q$  is detected in the CT 7, a reference voltage  $V_{gref}$  of the output terminal of the synchronous machine 1 is set in the voltage setting device 8 according to both the reactive current  $I_q$  and a reference voltage  $V_{href}$  of the high voltage side of the transformer 2 (step ST3).

Hereinafter, a setting method of the reference voltage  $V_{gref}$  is described.

A relation between the voltage  $V_g$  of the output terminal of the synchronous machine 1 and a voltage  $V_H$  of the high voltage side of the transformer 2 is expressed according to an equation (1).

$$V_g = V_H + X_t \times I_q \quad (1)$$

Here, the symbol  $X_t$  in the equation (1) denotes a reactance of the transformer 2.

Also, as shown in Fig. 3, in cases where a plurality of synchronous machines 1 are connected to a power transmission system, reactance of each synchronous machine 1 with another synchronous machine 1 is equal to almost zero by applying the equation (1) as a relation between the reference voltage  $V_{gref}$  and the reference voltage  $V_{href}$ , a cross

current flows from one synchronous machine 1 to another synchronous machine 1 due to both a voltage difference of the output terminal voltages  $V_g$  and a response difference in each synchronous machine 1 with another synchronous machine 1, and each synchronous machine 1 has an excessive load. To suppress the generation of the cross current, as is expressed according to an equation (2), a reactance  $X_{DR}$  corresponding to the suppression of the cross current is subtracted from the reactance  $X_t$  of the transformer 2. Here, the reactance  $X_{DR}$  corresponding to the suppression of the cross current is set to a value equal to several % of the reactance  $X_t$  of the transformer 2, and the value of the reactance  $X_{DR}$  is empirically set.

$$V_{Gref} = V_{Href} + (X_t - X_{DR}) \times I_q \quad (2)$$

Therefore, the reference voltage  $V_{Gref}$  of the output terminal of the synchronous machine 1 is calculated in the voltage setting device 8 by substituting the reactive current  $I_q$  output from the synchronous machine 1 and the reference voltage  $V_{Href}$  of the high voltage side of the transformer 2 into the equation (2).

When the reference voltage  $V_{Gref}$  of the output terminal of the synchronous machine 1 is set in the voltage setting device 8, the voltage  $V_g$  of the output terminal of the synchronous machine 1 detected in the PT 6 is subtracted in the subtracting unit 9 from the reference voltage  $V_{Gref}$  set in the voltage setting device 8 to obtain a subtraction value, and a difference signal indicating the subtraction value is output (step ST4).

When the difference signal is output from the subtracting unit 9, a timing signal for controlling a commutation timing of the exciter 11 is produced in the AVR 10, for example, by using the difference signal as an input condition for a following transfer function (step ST5).

$$\text{Transfer Function} = K \times (1 + T_{LD} \times s) / (1 + T_{LG} \times s) \quad (3)$$

Here, the symbol  $K$  denotes a gain constant, the symbols  $T_{LD}$  and  $T_{LG}$  denote time constants, and the symbol  $s$  denotes a Laplace operator.

When the timing signal output from the AVR 10 is received in the exciter 11, a field current is supplied to the field winding 12 of the synchronous machine 1 according to the timing signal (step ST6). Here, when the difference signal output from the subtracting unit 9 is equal to a positive value, the field current supplied to the field winding 12 is increased, and the voltage  $V_G$  of the output terminal of the synchronous machine 1 is heightened. In contrast, when the difference signal output from the subtracting unit 9 is equal to a negative value, the field current supplied to the field winding 12 is decreased, and the voltage  $V_G$  of the output terminal of the synchronous machine 1 is lowered.

Therefore, the voltage  $V_G$  of the output terminal of the synchronous machine 1 is controlled so as to agree with the reference voltage  $V_{Gref}$ . Also, when the reactive current  $I_Q$  output from the synchronous machine 1 is equal to zero, the voltage  $V_H$  of the high voltage side of the transformer 2 is controlled so as to agree with the reference voltage  $V_{Href}$ .

$$V_G = V_{Href} + (X_t - X_{DR}) \times I_Q \quad (4)$$

$$V_H = V_{Href} - X_{DR} \times I_Q \quad (5)$$

Therefore, because the voltage of the power transmission bus line is maintained to a constant value, even though a failure occurs, for example, in the power transmission line 4, the lowering of the voltage in the whole power transmission system can be lessened.

Because the conventional excitation control device has the above-described configuration, even though a failure occurs in the power transmission line 4, the lowering of the voltage in the whole power transmission system can be lessened. However, because no means for quickening the attenuation of an electric power fluctuation of

power transmission system occurring due to a failure of the power transmission system is arranged in the conventional excitation control device, a problem has arisen that it is required to additionally arrange a power system stabilization control device (PSS) for the purpose of quickening the attenuation of an electric power fluctuation.

The present invention is provided to solve the above-described problem, and the object of the present invention is to provide an excitation control device and an excitation control method in which the attenuation of an electric power fluctuation is quickened while controlling a voltage of the high voltage side of a transformer to a constant value.

#### DISCLOSURE OF THE INVENTION

An excitation control device of the present invention comprises a voltage setting means for setting a reference voltage of an output terminal of a synchronous machine according to a reactive current detected by a reactive current detecting means, a reference voltage of an output side of a transformer and a function of phase compensation used to quicken the attenuation of an electric power fluctuation.

Therefore, a voltage on the output side of the transformer can be set to a constant value, and the attenuation of the electric power fluctuation can be quickened.

In the excitation control device of the present invention, the reference voltage of the output terminal of the synchronous machine is set by the voltage setting means by considering the voltage of the output terminal of the synchronous machine detected by the voltage detecting means.

Therefore, the attenuation of the electric power fluctuation can be adjusted to a desired speed.

An excitation control method of the present invention comprises the step of setting a reference voltage of an output terminal of a synchronous machine according to a reactive current output from the synchronous machine, a reference voltage of an output side of a transformer and a function of phase compensation used to quicken the attenuation of an electric power fluctuation.

Therefore, a voltage on the output side of the transformer can be set to a constant value, and the attenuation of the electric power fluctuation can be quickened.

In the excitation control method of the present invention, the reference voltage of the output terminal of the synchronous machine is set by considering the voltage of the output terminal of the synchronous machine.

Therefore, the attenuation of the electric power fluctuation can be adjusted to a desired speed.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is constitutional view of a conventional excitation control device.

Fig. 2 is a flow chart showing a conventional excitation control method.

Fig. 3 is a system view showing an infinite bus line model.

Fig. 4 is constitutional view of an excitation control device according to a first embodiment of the present invention.

Fig. 5 is a flow chart showing an excitation control method according to the first embodiment of the present invention.

Fig. 6 is an explanatory view showing an internal configuration of a voltage setting device with electric power system stabilization function.

Fig. 7 is constitutional view of an excitation control device

according to a second embodiment of the present invention.

Fig. 8 is a flow chart showing an excitation control method according to the second embodiment of the present invention.

Fig. 9 is an explanatory view showing an internal configuration of a voltage setting device with electric power system stabilization function.

#### BEST MODE FOR CARRYING OUT THE INVENTION

Hereinafter, the best mode for carrying out the present invention will now be described with reference to the accompanying drawings to explain the present invention in more detail.

#### EMBODIMENT 1

Fig. 4 is constitutional view of an excitation control device according to a first embodiment of the present invention. In Fig. 4, 21 indicates a synchronous machine. 22 indicates a transformer. 23 indicates a circuit breaker. 24 indicates a power transmission line. 25 indicates a power transmission bus line of a power plant. 26 indicates a PT (or a voltage detecting means), denoting a potential transformer, for detecting a voltage  $V_o$  of an output terminal of the synchronous machine 21. 27 indicates a CT (or a reactive current detecting means), denoting a current transformer, for detecting a reactive current  $I_o$  output from the synchronous machine 21. 28 indicates a voltage setting device with electric power system stabilization function (or a voltage setting means) for setting a reference voltage  $V_{Gref}$  of the output terminal of the synchronous machine 21 according to the reactive current  $I_o$  detected in the CT 27, a reference voltage  $V_{Href}$  of the high voltage side of the transformer 22 and a transfer function  $F_{HI}(s)$  of phase compensation used to quicken the attenuation of an electric power fluctuation of a power transmission system.



29 indicates a subtracting unit for subtracting the output terminal voltage  $V_o$  detected in the PT 26 from the reference voltage  $V_{Gref}$  set in the voltage setting device with electric power system stabilization function 28 to produce a subtraction value and outputting a difference signal indicating the subtraction value. 30 indicates an AVR, denoting an automatic voltage regulating device, for controlling a commutation timing of an exciter 31 by using the difference signal output from the subtracting unit 29 as an input condition for a transfer function of commutation timing. 31 indicates the exciter for supplying a field current to a field winding 32 of the synchronous machine 21 according to an instruction of the AVR 30. 32 indicates the field winding of the synchronous machine 21. Here, control means comprises the subtracting unit 29, the AVR 30 and the exciter 31.

Fig. 5 is a flow chart showing an excitation control method according to a first embodiment of the present invention, and Fig. 6 is an explanatory view showing an internal configuration of the voltage setting device with electric power system stabilization function 28.

Next an operation will be described below.

A voltage  $V_o$  of the output terminal of the synchronous machine 21 is detected in the PT 26 (step ST11), and a reactive current  $I_q$  output from the synchronous machine 21 is detected in the CT 27 (step ST12).

When the reactive current  $I_q$  is detected in the CT 27, a reference voltage  $V_{Gref}$  of the output terminal of the synchronous machine 21 is set in the voltage setting device with electric power system stabilization function 28 according to the reactive current  $I_q$ , a reference voltage  $V_{Href}$  of the high voltage side of the transformer 22 and a transfer function  $F_{HI}(s)$  of phase compensation used to quicken the attenuation of an electric power fluctuation (step ST13). In detail, the reference voltage  $V_{Gref}$  of the output terminal of the synchronous machine 21 is calculated by substituting the reactive current  $I_q$ , the

reference voltage  $V_{Href}$  and the transfer function  $F_{H1}(s)$  into the equation (6) (refer to Fig. 6).

$$V_{Gref} = V_{Href} + F_{H1}(s) \times (X_t - X_{DR}) \times I_q \quad (6)$$

Here, the symbol  $X_t$  in the equation (6) denotes a reactance of the transformer 22, and the symbol  $X_{DR}$  denotes a reactance corresponding to the suppression of a cross current flowing in cases where a plurality of synchronous machines 21 are connected to a power transmission line. Also,  $F_{H1}(s)$  denotes a transfer function in a phase compensation circuit in which a signal indicating a timing appropriate to quicken the attenuation of an electric power fluctuation is produced. For example,  $F_{H1}(s)$  is set to a transfer function expressed according to an equation (7).

$$F_{H1}(s) = a_{1n} \times s^n + a_{1(n-1)} \times s^{n-1} + \dots + a_{11} \times s + a_{10} \quad (7)$$

wherein the symbol  $s$  denotes a Laplace operator, and the symbols  $a$  denote constant values respectively.

Here, to make a voltage  $V_H$  of the high voltage side of the transformer 22 agree with the reference voltage  $V_{Href}$  in a normal operation, it is required to set each constant  $a$  of the equation (7) so as to set a gain of  $F_{H1}(s)$  to 1 in the normal operation.

Thereafter, when the reference voltage  $V_{Gref}$  of the output terminal of the synchronous machine 21 is set in the voltage setting device with electric power system stabilization function 28, the voltage  $V_G$  of the output terminal of the synchronous machine 21 detected in the PT 26 is subtracted in the subtracting unit 29 from the reference voltage  $V_{Gref}$  set in the voltage setting device with electric power system stabilization function 28 to obtain a subtraction value, and a difference signal indicating the subtraction value is output (step ST14).

Thereafter, a timing signal for controlling a commutation timing of the exciter 31 is produced in the AVR 30 when the difference signal

output from the subtracting unit 29 is received as an input signal (step ST15).

Thereafter, when the timing signal output from the AVR 30 is received in the exciter 31, a field current is supplied from the exciter 31 to the field winding 32 of the synchronous machine 21 according to the timing signal (step ST16).

Here, when the difference signal output from the subtracting unit 29 is equal to a positive value, the field current supplied to the field winding 32 is increased, and the voltage  $V_g$  of the output terminal of the synchronous machine 21 is heightened. In contrast, when the difference signal output from the subtracting unit 29 is equal to a negative value, the field current supplied to the field winding 32 is decreased, and the voltage  $V_g$  of the output terminal of the synchronous machine 21 is lowered.

Therefore, the voltage  $V_g$  of the output terminal of the synchronous machine 21 is controlled so as to agree with the reference voltage  $V_{Gref}$ .

Also, the voltage  $V_g$  of the output terminal of the synchronous machine 21 has relation to the voltage  $V_H$  of the high voltage side of the transformer 22 according to an equation (8). Therefore, the voltage  $V_g$  of the output terminal of the synchronous machine 21 and the voltage  $V_H$  of the high voltage side of the transformer 22 are expressed according to equations (9) and (10) respectively by using the reference voltage  $V_{Href}$  of the high voltage side of the transformer 22.

$$V_H = V_g - X_t \times I_Q \quad (8)$$

$$V_g = V_{Href} + (X_t - X_{DR}) \times I_Q \quad (9)$$

$$V_H = V_{Href} - X_{DR} \times I_Q \quad (10)$$

Therefore, when the reactive current  $I_Q$  output from the synchronous machine 21 is equal to zero, the voltage  $V_H$  of the high voltage side of the transformer 22 can be controlled so as to agree with the

reference voltage  $V_{Href}$ .

As is described above, in the first embodiment, the reference voltage  $V_{Gref}$  of the output terminal of the synchronous machine 21 is set according to the reactive current  $I_q$  output from the synchronous machine 21, the reference voltage  $V_{Href}$  of the high voltage side of the transformer 22 and the transfer function  $F_{H1}(s)$  of phase compensation used to quicken the attenuation of an electric power fluctuation. Therefore, the voltage  $V_H$  of the high voltage side of the transformer 22 can be controlled to a constant value. As a result, even though a failure occurs in the power transmission system or a load on the power transmission system is rapidly increased, the voltage  $V_H$  of the high voltage side of the transformer 22 can be stabilized. Also, because the attenuation of an electric power fluctuation can be quickened, the steady-state stability in an electric power system can be heightened.

## EMBODIMENT 2

Fig. 7 is constitutional view of an excitation control device according to a second embodiment of the present invention. The constituent elements, which are the same as those shown in Fig. 4, are indicated by the same reference numerals as those of the constituent elements shown in Fig. 4, and additional description of those constituent elements is omitted.

33 indicates a voltage setting device with electric power system stabilization function (or a voltage setting means) for setting a reference voltage  $V_{Gref}$  of the output terminal of the synchronous machine 21 according to a reactive current  $I_q$  detected in the CT 27, an output terminal voltage  $V_o$  detected in the PT 26, a reference voltage  $V_{Href}$  of the high voltage side of the transformer 22 and a transfer function  $F_{H2}(s)$  of phase compensation used to quicken the attenuation

of an electric power fluctuation.

Fig. 8 is a flow chart showing an excitation control method according to the second embodiment of the present invention, Fig. 9 is an explanatory view showing an internal configuration of the voltage setting device with electric power system stabilization function 33.

Next an operation will be described below.

In the first embodiment, the reference voltage  $V_{Gref}$  of the output terminal of the synchronous machine 21 is set according to the reactive current  $I_Q$  output from the synchronous machine 21, the reference voltage  $V_{Href}$  of the high voltage side of the transformer 22 and the transfer function  $F_{H1}(s)$  of phase compensation used to quicken the attenuation of an electric power fluctuation. However, it is preferred that a reference voltage  $V_{Gref}$  of the output terminal of the synchronous machine 21 is set by considering an output terminal voltage  $V_G$  detected in the PT 26.

In detail, as shown in Fig. 9, a reference voltage  $V_{Gref}$  of the output terminal of the synchronous machine 21 is set in the voltage setting device with electric power system stabilization function 33 according to a reactive current  $I_Q$  detected in the CT 27, an output terminal voltage  $V_G$  detected in the PT 26, a reference voltage  $V_{Href}$  of the high voltage side of the transformer 22 and a transfer function  $F_{H2}(s)$  of phase compensation used to quicken the attenuation of an electric power fluctuation (step ST17).

$$V_{Gref} = V_{Href} + (X_t - X_{DR}) \times I_Q + \{V_{Href} + (X_t - X_{DR}) \times I_Q - V_G\} \times F_{H2}(s) \quad (11)$$

Here, the symbol  $X_t$  in the equation (11) denotes a reactance of the transformer 22, and the symbol  $X_{DR}$  denotes a reactance corresponding to the suppression of a cross current flowing in cases where a plurality of synchronous machines 21 are connected to a power transmission line. Also,  $F_{H2}(s)$  denotes a transfer function in a phase compensation circuit

in which a signal indicating a timing appropriate to quicken the attenuation of an electric power fluctuation is produced. For example,  $F_{H2}(s)$  is set to a transfer function expressed according to an equation (12).

$$F_{H2}(s) = a_{2n} \times s^n + a_{2(n-1)} \times s^{n-1} + \dots + a_{21} \times s + a_{20} \quad (12)$$

wherein the symbol  $s$  denotes a Laplace operator, and the symbols  $a$  denote constant values respectively.

As is described above, in cases where the reference voltage  $V_{Gref}$  of the output terminal of the synchronous machine 21 is calculated, even though the transfer function  $F_{H2}(s)$  is set to any value, the voltage  $V_H$  of the high voltage side of the transformer 22 agrees with the reference voltage  $V_{Href}$  in a normal operation (because  $V_{Href} + (X_t - X_{DR}) \times I_Q - V_e = 0$  is satisfied in the normal operation). Therefore, the excitation control device of the second embodiment differs from that of the first embodiment in that it is not required to set a gain of  $F_{H2}(s)$  to 1 in the normal operation, and the attenuation of an electric power fluctuation can be adjusted to a desired speed.

## INDUSTRIAL APPLICABILITY

As is described above, in cases where an exciting system of a synchronous machine is controlled, the excitation control device and the excitation control method according to the present invention is  
5 appropriate to perform the stabilization of voltage in an electric power system and the improvement of steady-state stability in the electric power system.

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## WHAT IS CLAIMED IS:

## 1. An excitation control device, comprising:

voltage detecting means for detecting a voltage of an output terminal of a synchronous machine which is connected to a power transmission system through a transformer;

reactive current detecting means for detecting a reactive current output from the synchronous machine;

voltage setting means for setting a reference voltage of the output terminal of the synchronous machine according to the reactive current detected by the reactive current detecting means, a reference voltage of an output side of the transformer and a function of phase compensation used to quicken the attenuation of an electric power fluctuation; and

control means for controlling an exciting system of the synchronous machine according to a difference between the reference voltage set by the voltage setting means and the voltage of the output terminal of the synchronous machine detected by the voltage detecting means.

2. An excitation control device according to claim 1, wherein the reference voltage of the output terminal of the synchronous machine is set by the voltage setting means by considering the voltage of the output terminal of the synchronous machine detected by the voltage detecting means.

## 3. An excitation control method, comprising the steps of:

detecting a voltage of an output terminal of a synchronous machine which is connected to a power transmission system through a transformer;

detecting a reactive current output from the synchronous machine;

setting a reference voltage of the output terminal of the synchronous



machine according to the reactive current, a reference voltage of an output side of the transformer and a function of phase compensation used to quicken the attenuation of an electric power fluctuation; and

controlling an exciting system of the synchronous machine according  
5 to a difference between the reference voltage of the output terminal of the synchronous machine and the voltage of the output terminal of the synchronous machine.

4. An excitation control method according to claim 3, wherein the  
10 step of setting the reference voltage of the output terminal of the synchronous machine includes the step of

setting the reference voltage of the output terminal of the synchronous machine by considering the voltage of the output terminal of the synchronous machine.

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FIG.1

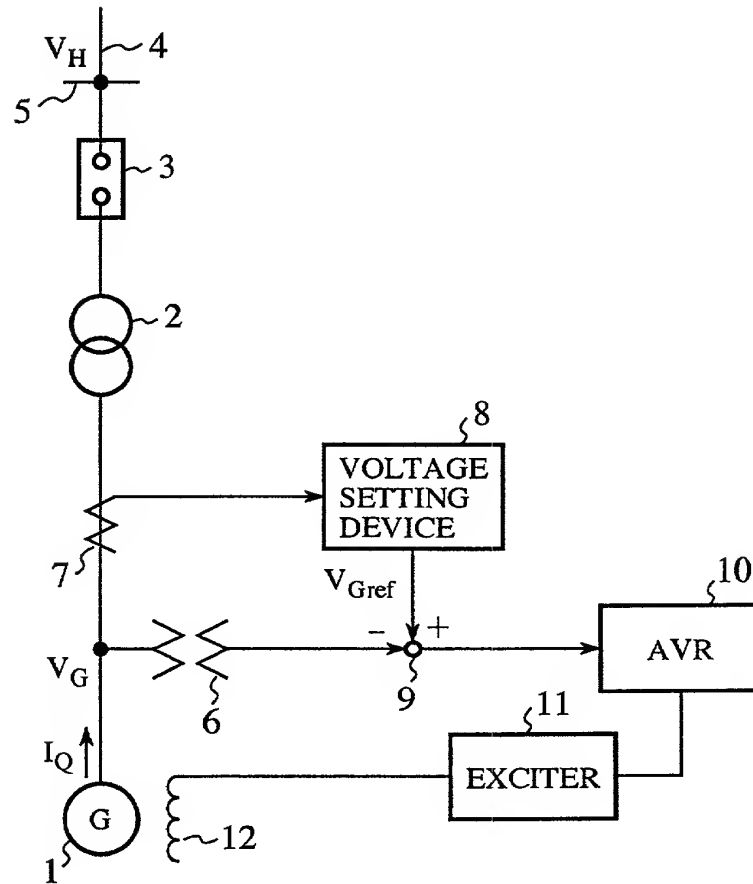


FIG.2

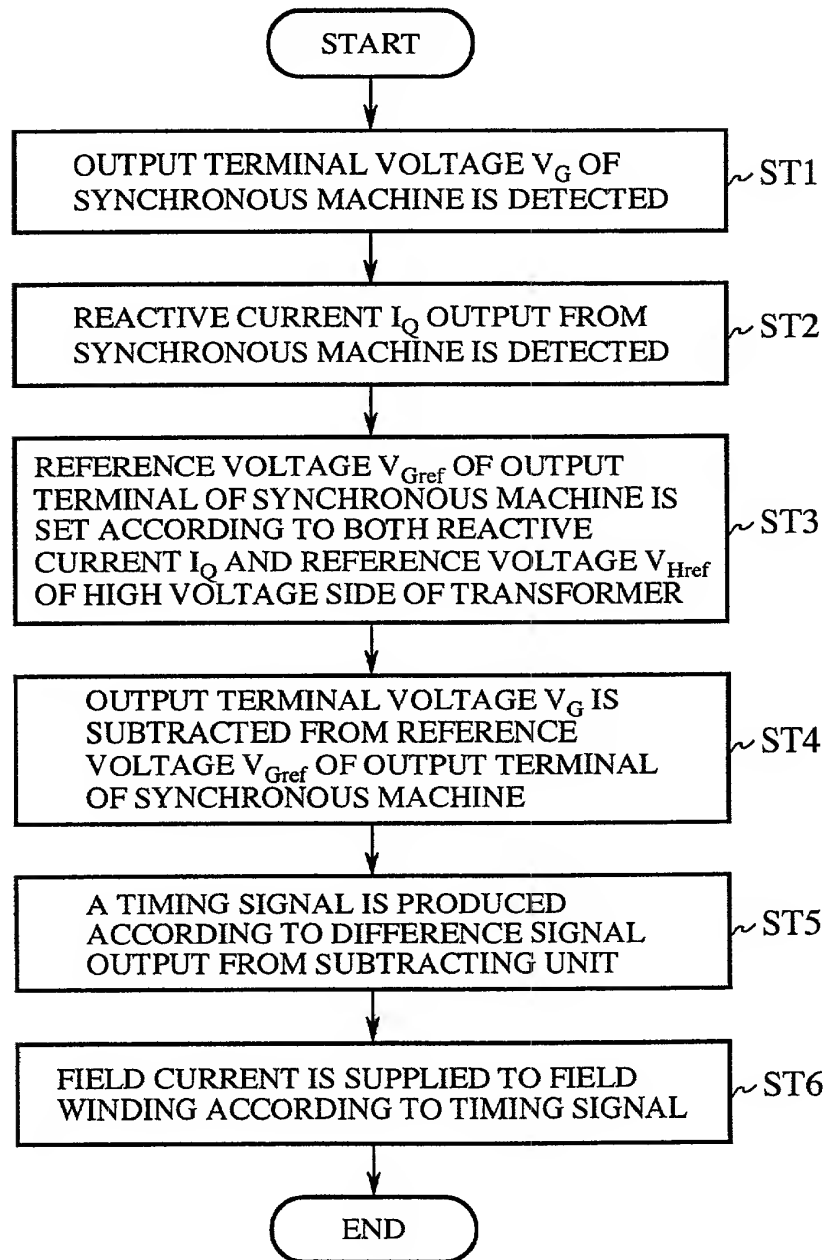


FIG.3

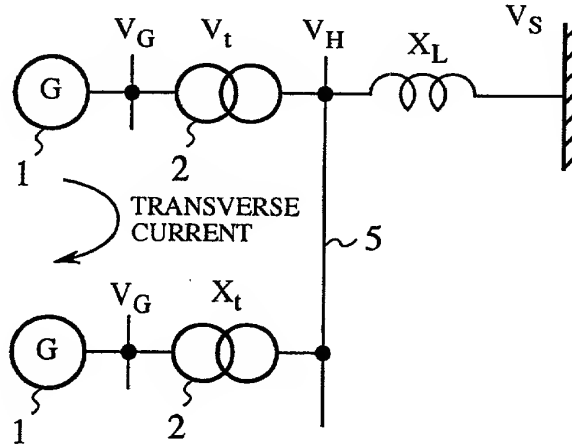


FIG.4

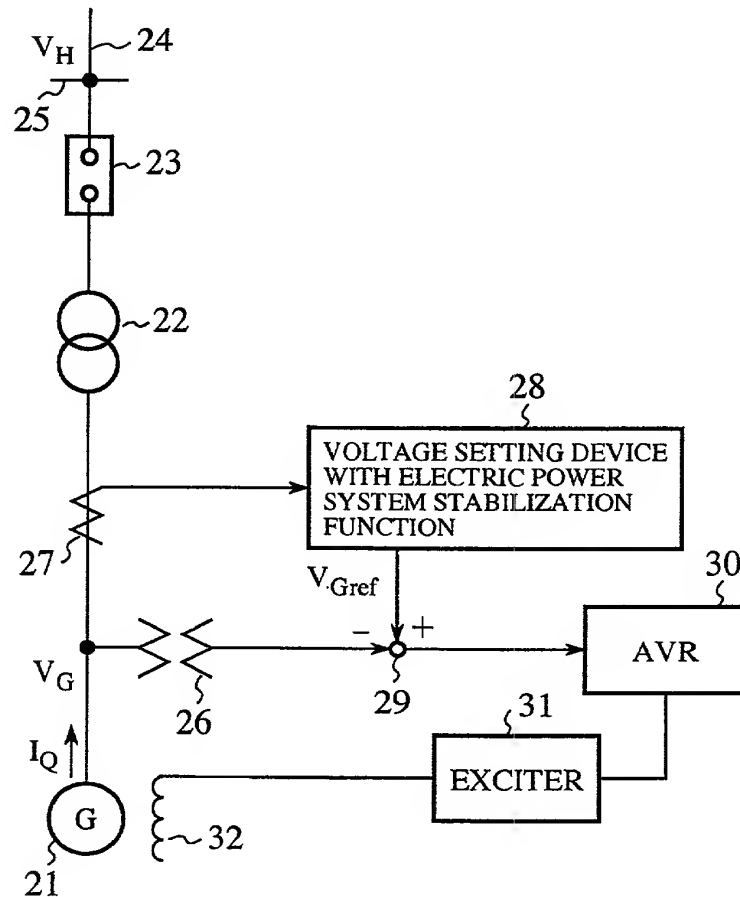


FIG.5

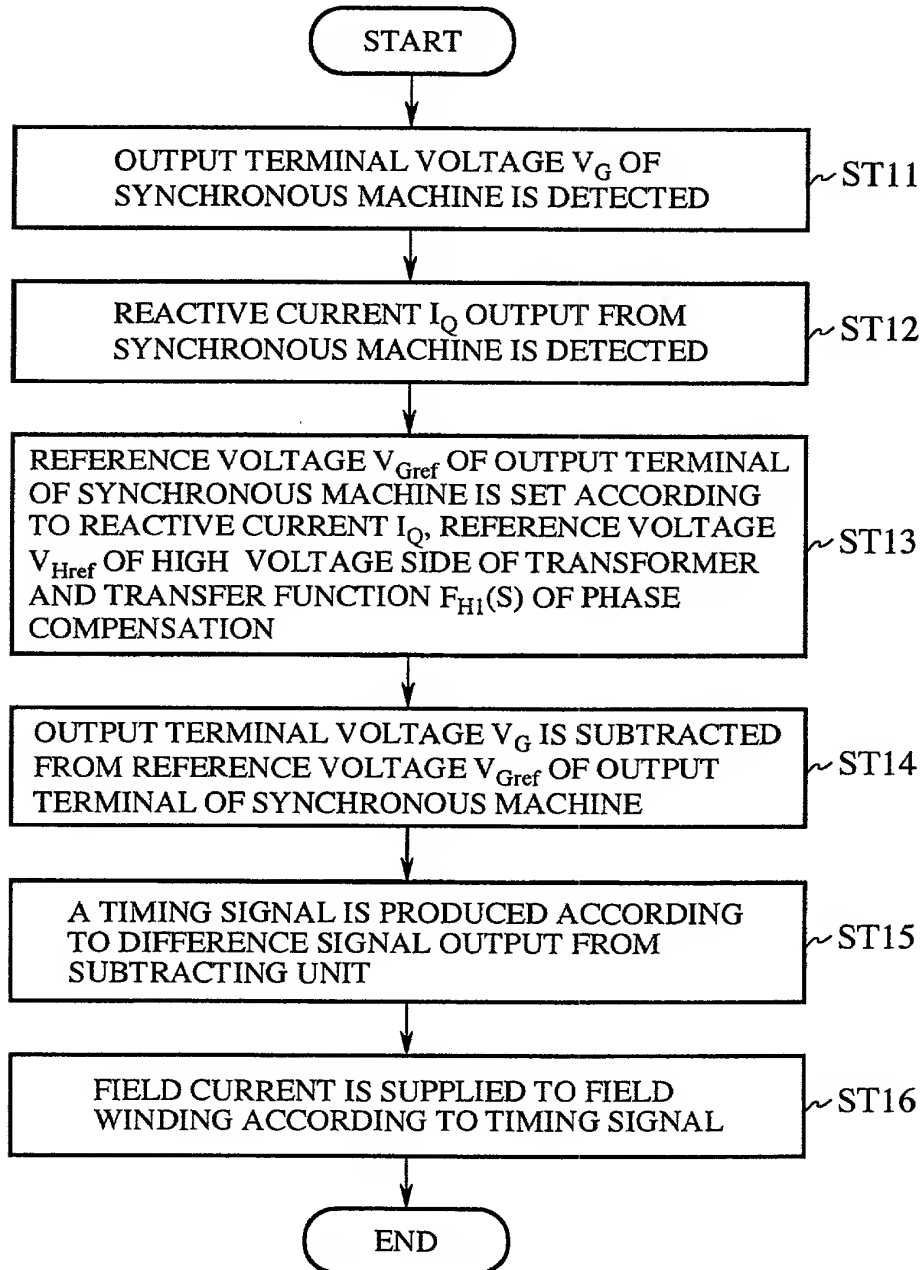


FIG.7

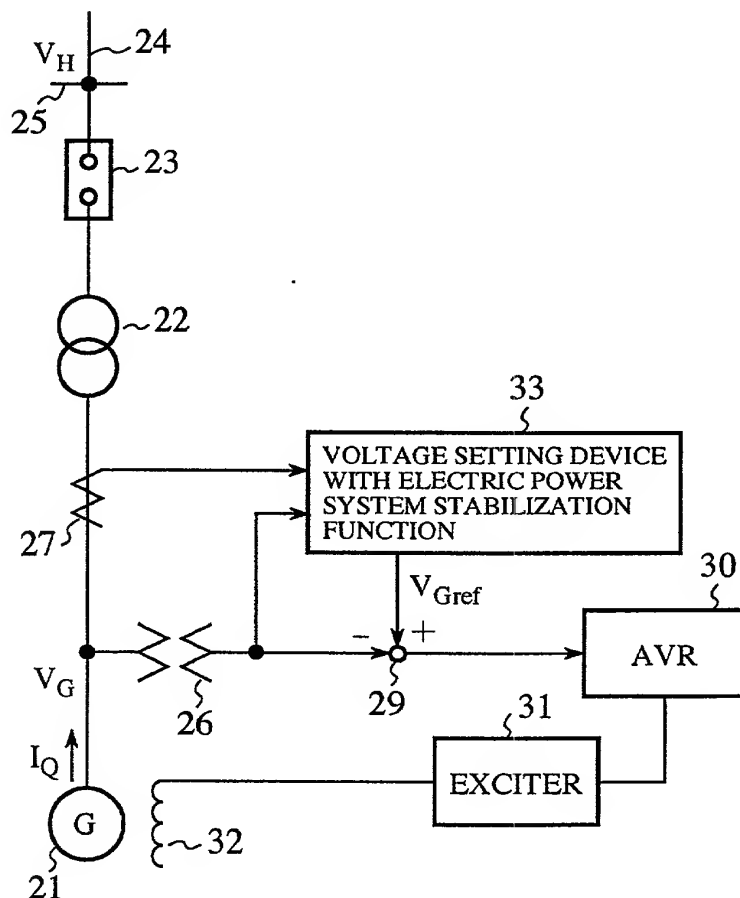


FIG.8

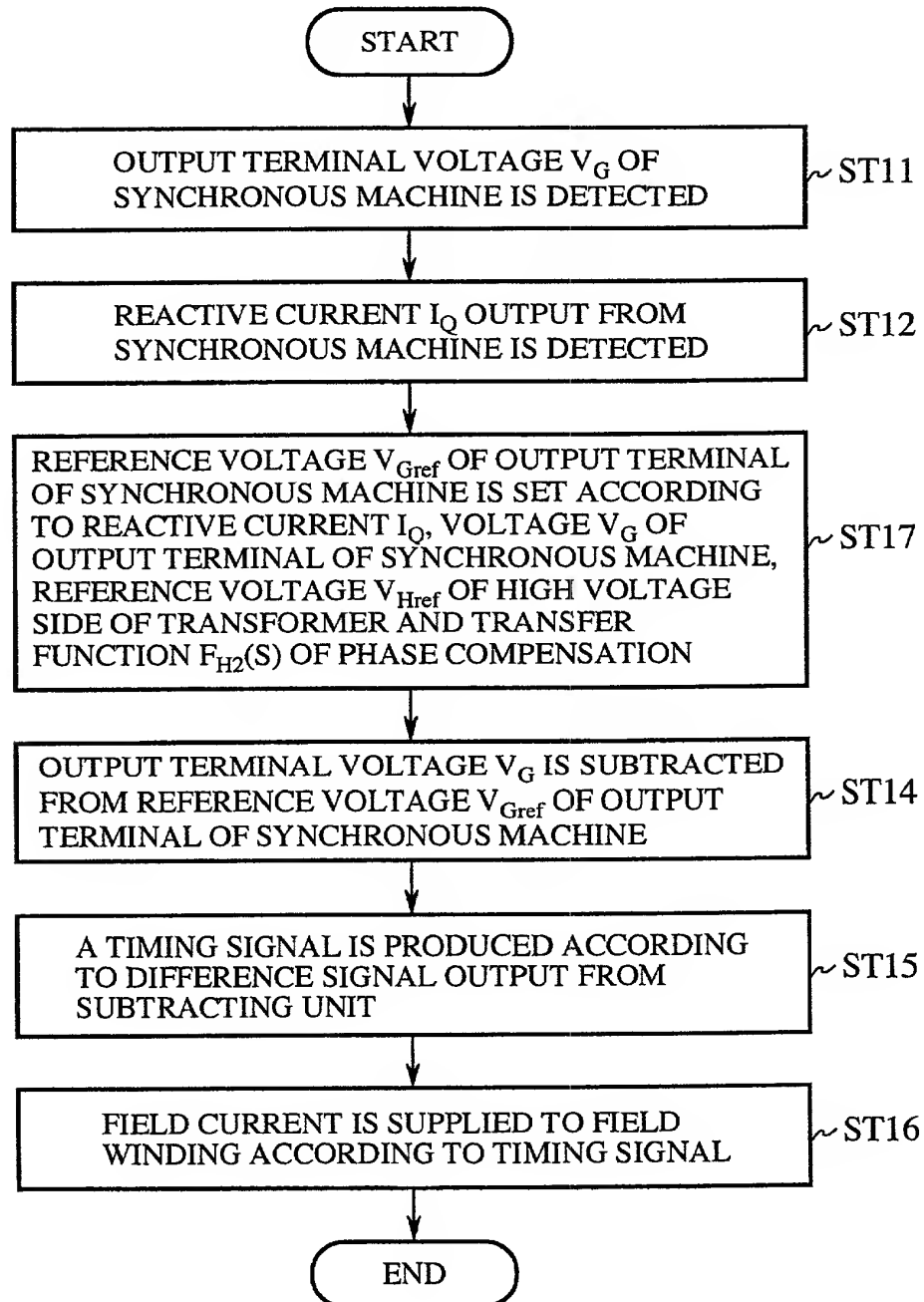
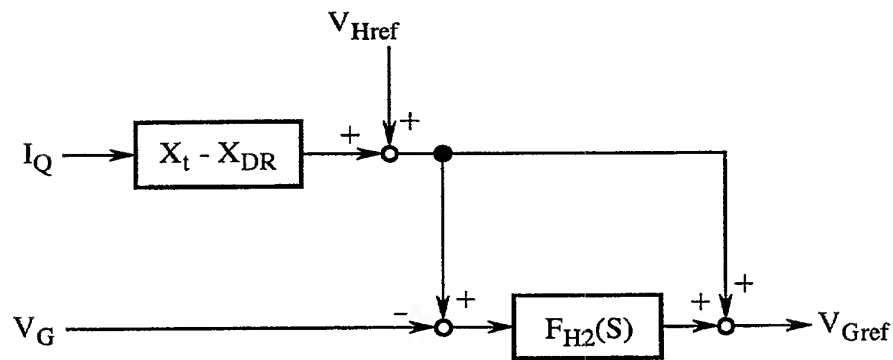


FIG.9





## COMBINED DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that:

This declaration is of the following type:

- ☐ original   ☐ design   ☐ supplemental  
☒ national stage of PCT  
☐ divisional   ☐ continuation   ☐ continuation-in-part

My residence, post office address, and citizenship are as stated below next to my name.

I believe I am the original, first, and sole inventor (*if only one name is listed below*) or an original, first, and joint inventor (*if plural names are listed below*) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

"EXCITATION CONTROL DEVICE AND EXCITATION CONTROL METHOD"

the specification of which:

- ☐ is attached hereto.  
☐ was filed on \_\_\_\_\_ as Application No. \_\_\_\_\_  
 and was amended on \_\_\_\_\_ (*if applicable*).  
☒ was filed on June 19, 2000 as PCT International Application No.  
 PCT/JP00/03994 and was amended pursuant to PCT Article 19 on  
 \_\_\_\_\_ (*if any*).

I state that I have reviewed and understand the contents of the specification identified above, including the claim(s), as amended by any amendment referred to above.

I acknowledge the duty to disclose information that is material to the examination of the application identified above in accordance with 37 CFR §1.56.

I claim foreign priority benefits pursuant to 35 USC §119(a) or §119(d) of any foreign application(s) for patent or inventor's certificate or of any PCT international patent application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent, utility model, design registration, or inventor's certificate or any PCT international patent application(s) designating at least one country other than the United States of America filed by me on the same subject matter and having a filing date before that of the application(s) from which the benefit of priority is claimed.

PRIOR FOREIGN PATENT, UTILITY MODEL, AND DESIGN REGISTRATION APPLICATIONS						
COUNTRY	PRIOR FOREIGN APPLICATION	DATE OF FILING (day,month,year)	PRIORITY CLAIMED UNDER 35 USC §119(a) or §119(d)			
				YES		NO
				YES		NO
				YES		NO

I claim the benefit pursuant to 35 USC §119(e) of the following United States provisional patent application(s):

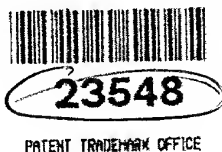
PRIOR U.S. PROVISIONAL PATENT APPLICATIONS, BENEFIT CLAIMED UNDER 35 USC §119(e)	
APPLICATION NO.	DATE OF FILING (day,month,year)

I claim the benefit pursuant to 35 USC §120 of any United States patent application(s) or PCT international patent application(s) designating the United States of America listed below and, insofar as the subject matter of each of the claims of this patent application is not disclosed in the prior patent application(s) in the manner provided by the first paragraph of 35 USC §112, I acknowledge the duty to disclose material information as defined in 37 CFR §1.56 effective between the filing date of the prior patent application(s) and the national or PCT international filing date of this patent application.

PRIOR U.S. PATENT APPLICATIONS OR PCT INTERNATIONAL PATENT APPLICATIONS DESIGNATING THE U.S., BENEFIT CLAIMED UNDER 35 USC §120					
U.S. PATENT APPLICATIONS			Status (check one)		
APPLICATION NO.	U.S. FILING DATE		PATENTED	PENDING	ABANDONED
1.					
2.					
3.					
PCT APPLICATIONS DESIGNATING THE U.S.			Status (check one)		
PCT APPLICATION NO.	PCT FILING DATE (day,month,year)	U.S. APPLICATION NOS. ASSIGNED (if any)	PATENTED	PENDING	ABANDONED
4.					
5.					
6.					

DETAILS OF FOREIGN APPLICATIONS FROM WHICH PRIORITY CLAIMED UNDER 35 USC §119 FOR ABOVE LISTED U.S./PCT APPLICATIONS				
ABOVE APPLN. NO.	COUNTRY	APPLICATION NO.	DATE OF FILING (day,month,year)	DATE OF ISSUE (day,month,year)
1.				
2.				
3.				
4.				
5.				
6.				

As a named inventor, I appoint the following registered practitioner(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith: Customer Number 23548.



I further direct that correspondence concerning this application be directed to Customer Number 23548.



I declare that all statements made herein of my own knowledge are true, that all statements made on information and belief are believed to be true, that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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209110" 99000001  
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